United States Patent [19]

Brooks

[11] **4,395,158**

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[54] **METHOD AND APPARATUS FOR ENTRENCHING AN ENLONGATED UNDER-WATER STRUCTURE**

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[51] **Int. Cl.**[3] **E02F 5/08**

[52] **U.S. Cl.** **405/161;** 37/62; 405/159

[58] **Field of Search** 405/158–164; 37/58, 61–63

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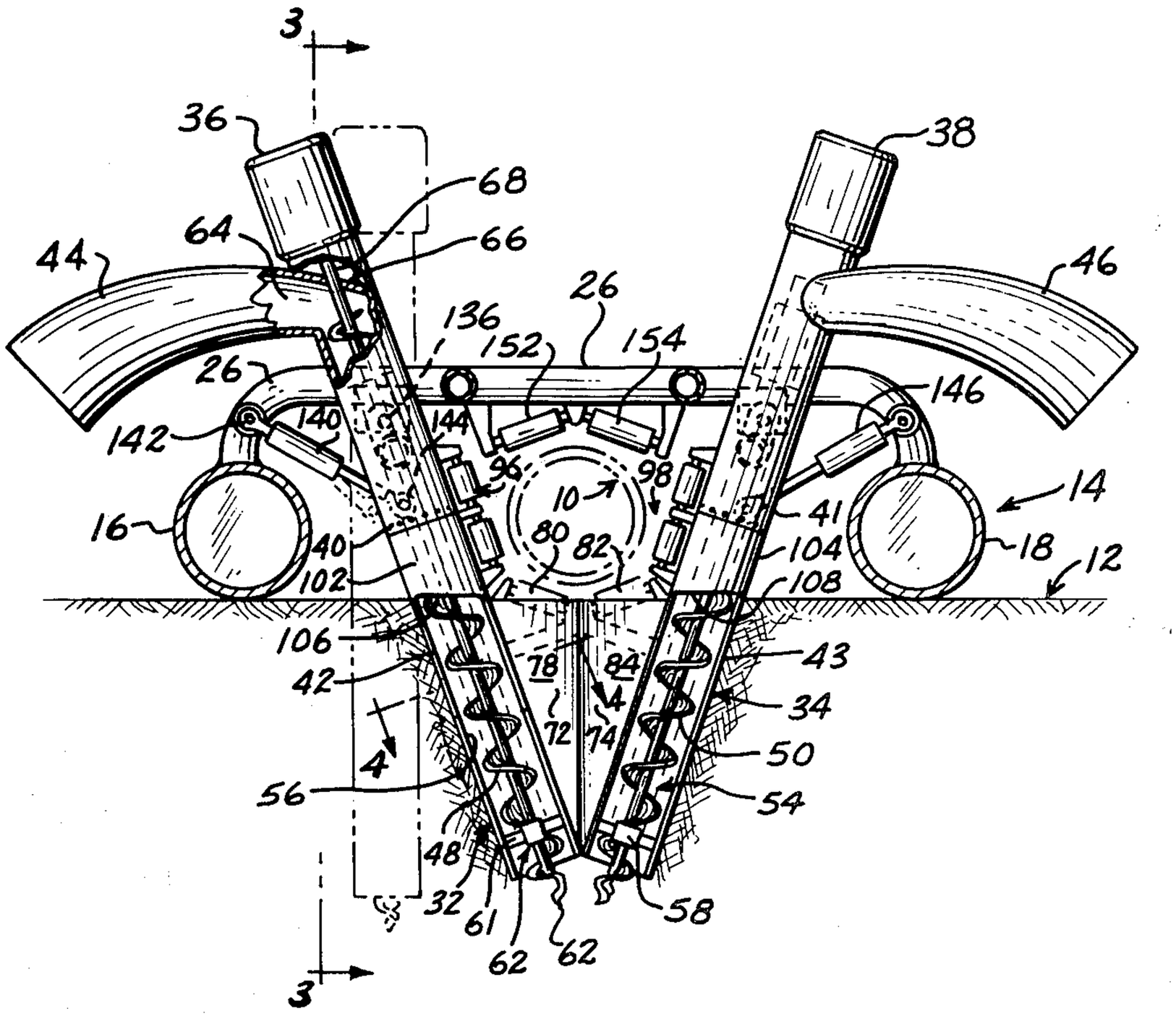
Primary Examiner—Dennis L. Taylor
Attorney, Agent, or Firm—Brisebois & Kruger

[57] **ABSTRACT**

A method and apparatus for entrenching under-water pipelines, in which auger assemblies are provided on a vehicle for inward tilting movement so that the auger assemblies both cut and convey bottom soil from the region beneath the pipeline. The respective augers are driven by hydraulic motors and can include deflectors for directing bottom soil toward the individual augers. In a variation, two sets of augers are provided on the vehicle in tandem.

14 Claims, 8 Drawing Figures



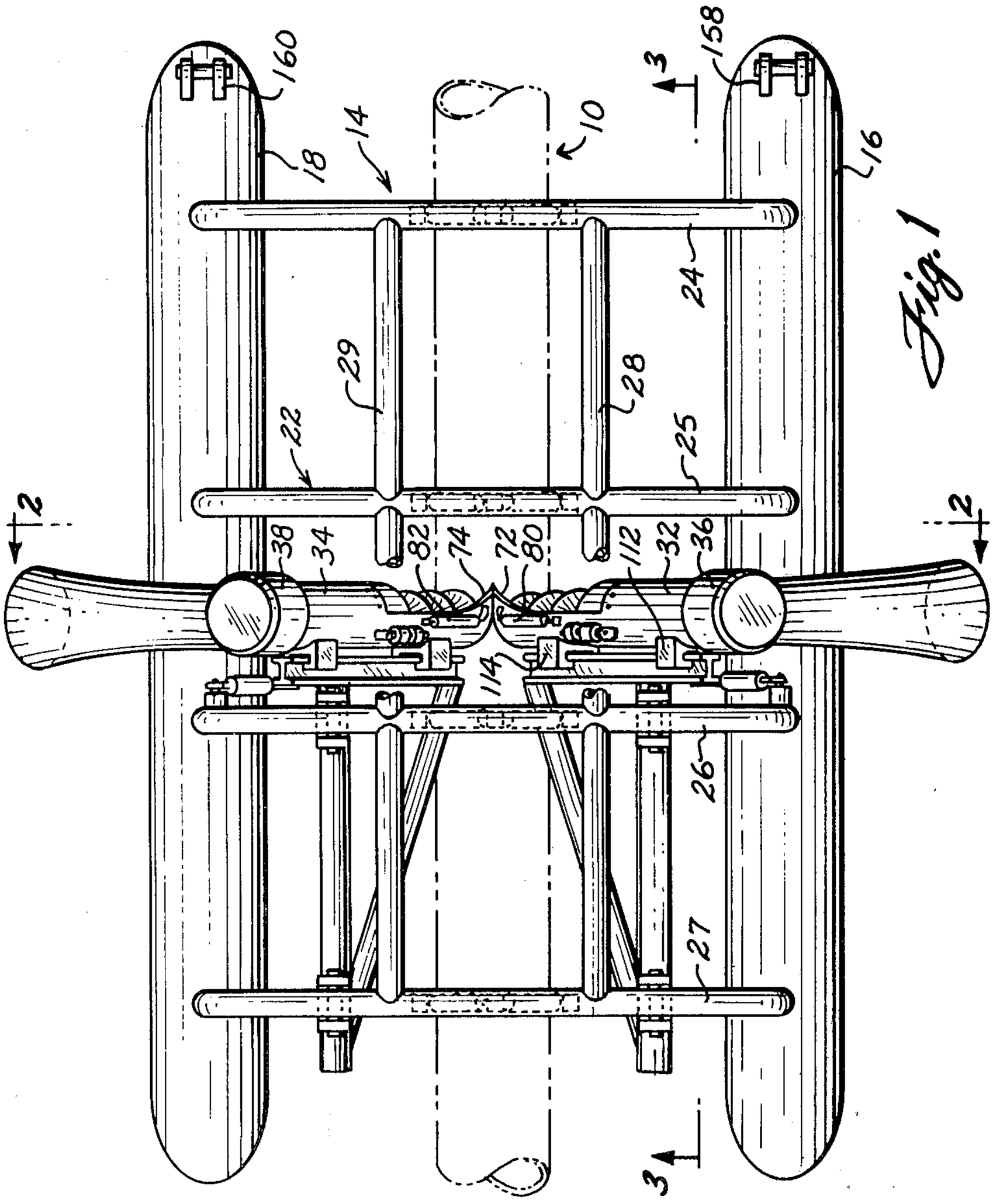

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Fig. 1

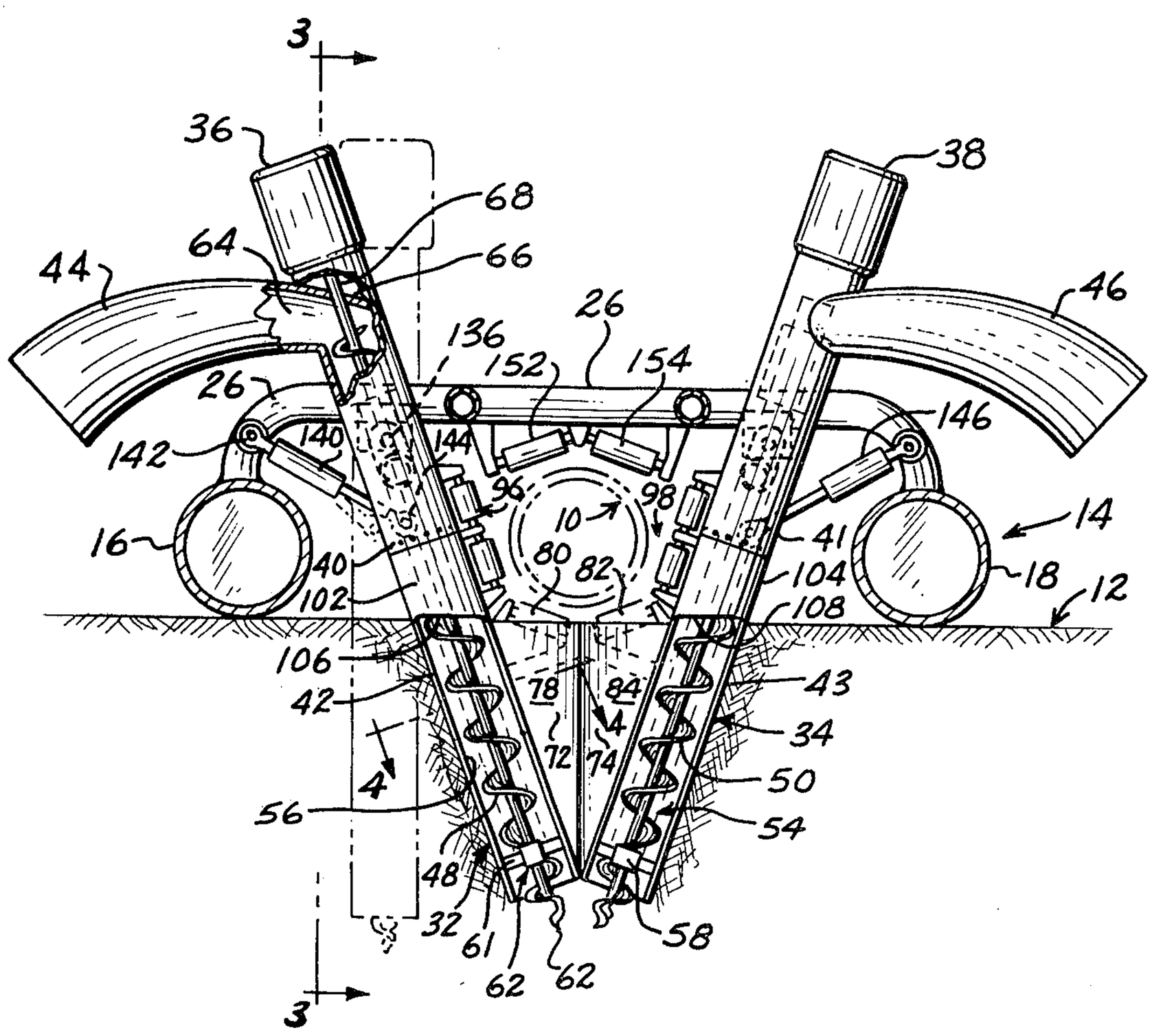
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Fig. 2

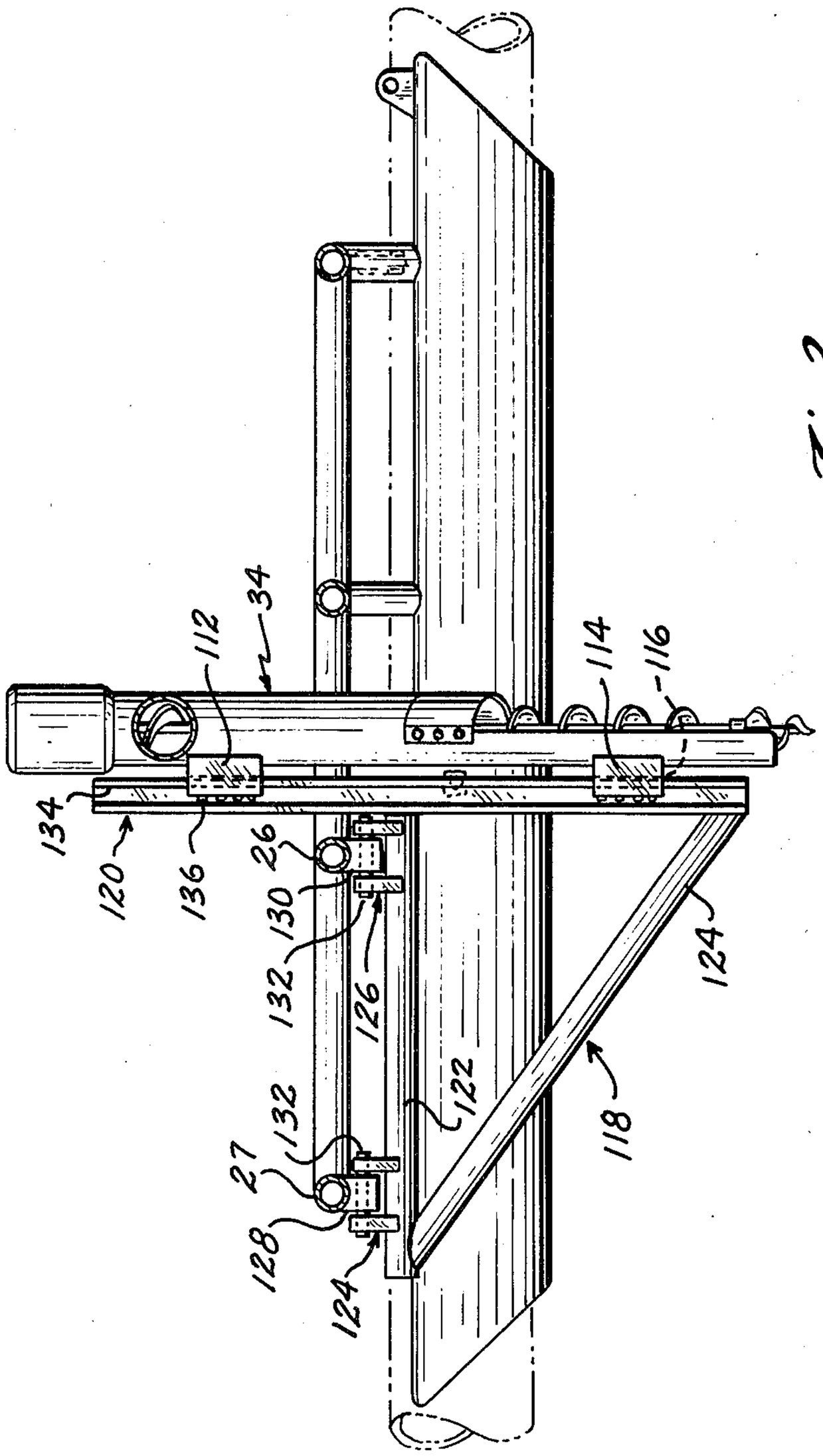
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Fig. 3

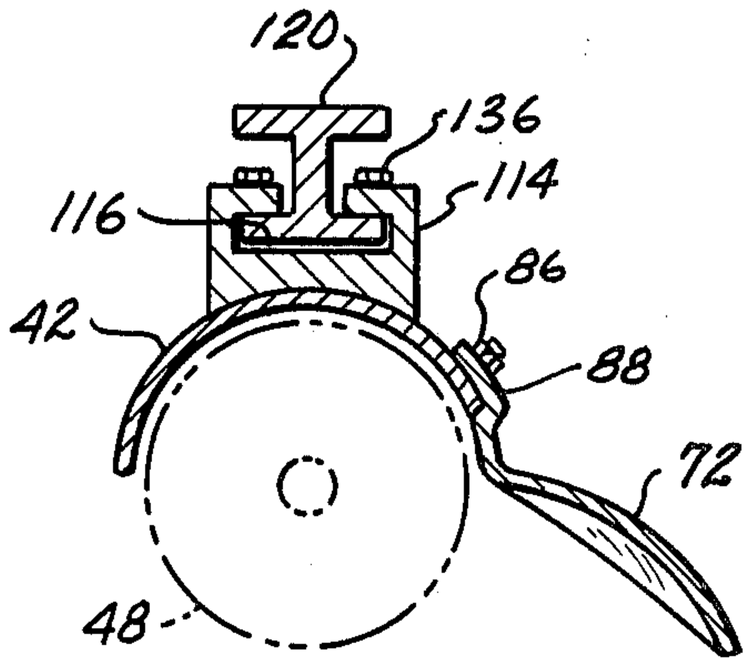

Fig. 4

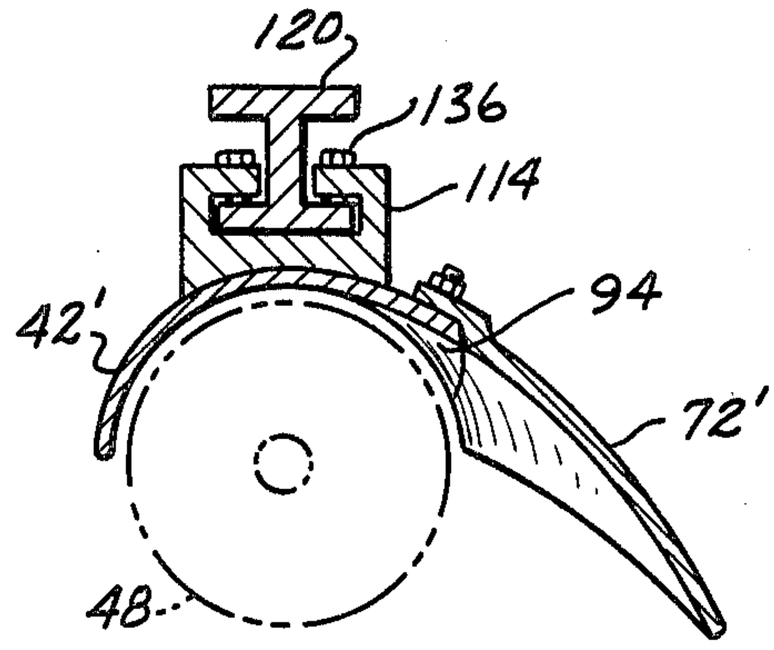

Fig. 5

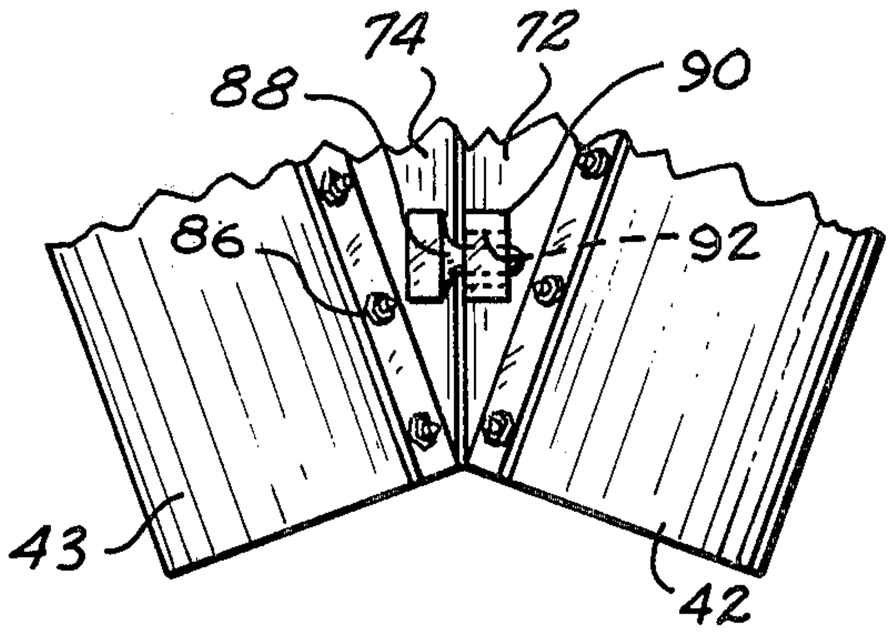

Fig. 6

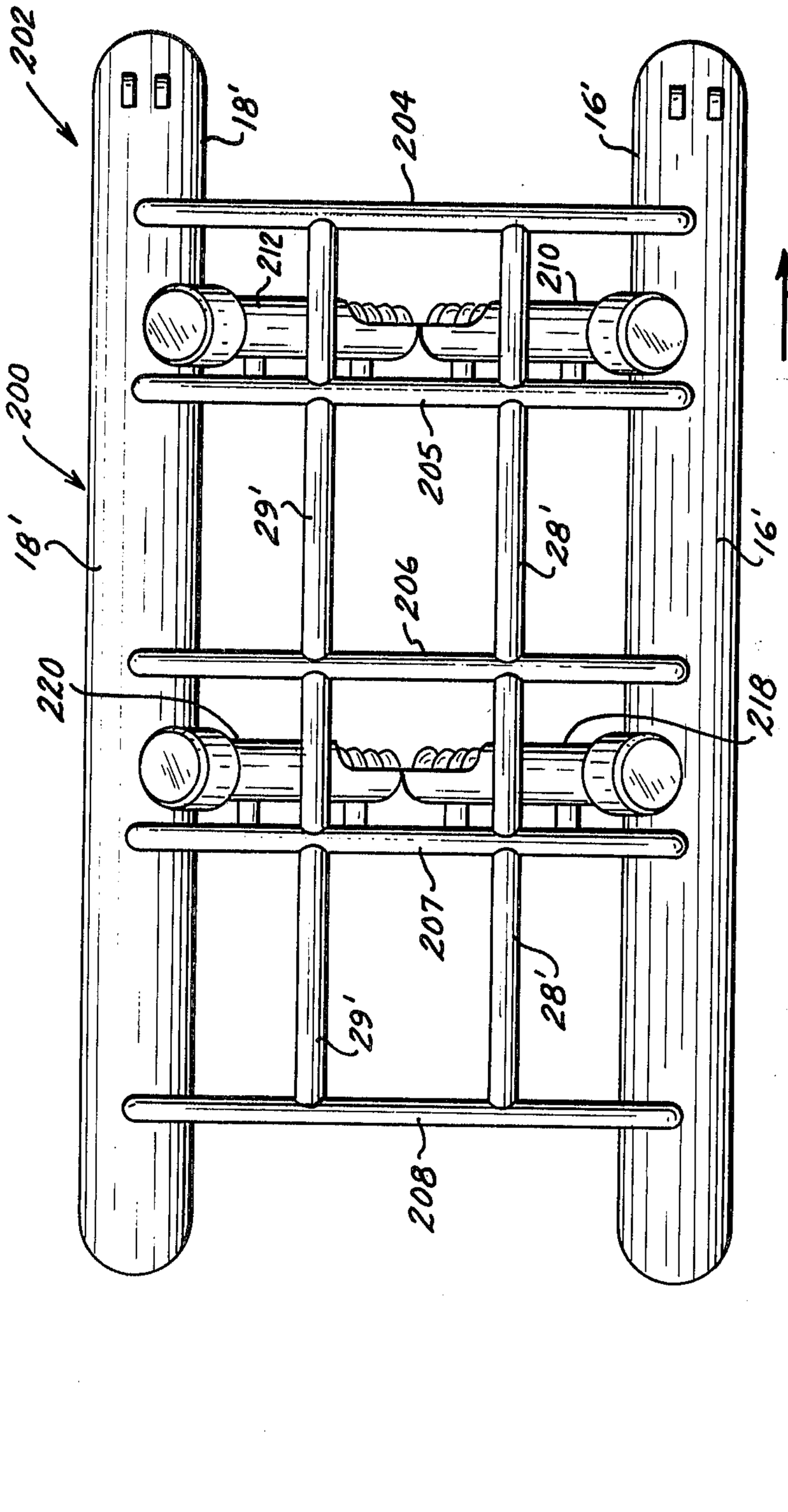
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Fig. 7

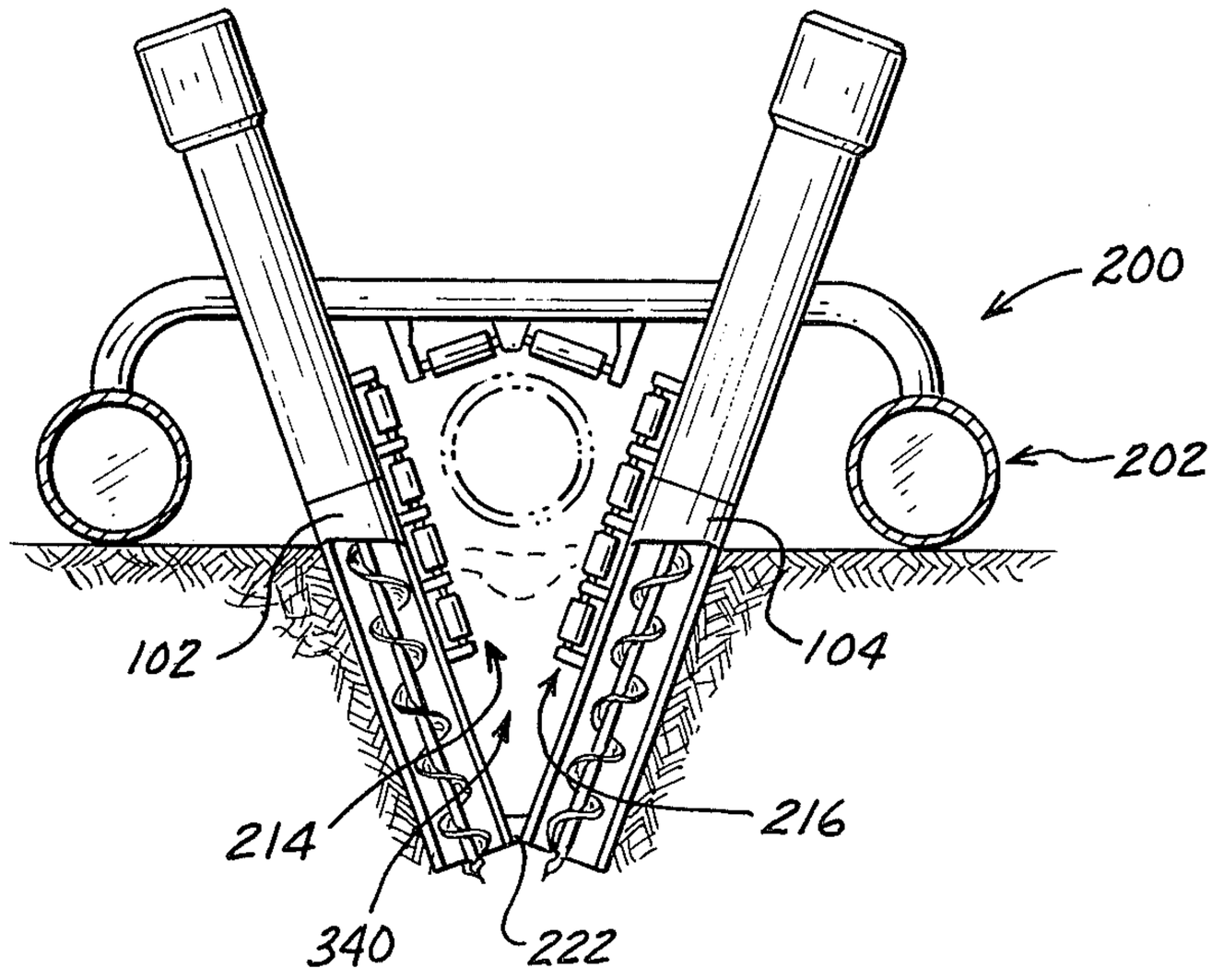

Fig. 8

METHOD AND APPARATUS FOR ENTRENCHING AN ENLONGATED UNDER-WATER STRUCTURE

BACKGROUND OF THE INVENTION

This invention relates to a method of entrenching an underwater structure such as a pipeline, and to an apparatus for forming trenches and entrenching a pipeline in accordance with the method.

When a pipeline or cable is placed on the floor of a body of water, for example, in the Gulf of Mexico, or the floor of an ocean, it is usually required that the pipeline be entrenched or buried in the floor of the body of water. Burying the pipeline or cable is desirable for various reasons, among others, to prevent damage to the line as a result of underwater currents, and to generally prevent damage to the line from passing ships where the line is located in relatively shallow water.

Typically, the pipeline is covered with a protective casing or coating of cement and/or asphalt. While it is usual to entrench a pipeline by first laying the pipeline on the bottom of the body of water and then forming a trench under the pipeline so that the pipeline gradually sinks into the trench, the pipeline or cable could be entrenched as it is fed from a pipe laying barge.

Numerous techniques and apparatus are known for entrenching submerged pipeline or cable. Among these are rotary mechanical cutters with or without high pressure fluid jets, frequently in combination with suction dredges. Typical examples of the prior art techniques and apparatus are shown and disclosed in the following U.S. Pat. Nos.:

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Dredges and high pressure jets, while quite effective for forming underwater trenches are expensive to operate because of the surface pumps and equipment required to operate the jets and the dredges. Further, where a suction dredge is used, the material sucked out of the trench is usually carried to the surface and then dumped with the result that any polutants on the ocean floor are mixed with the water and, in any event, the water becomes and stays muddy for a considerable period of time.

The mechanical cutters used in the past have not been wholly effective for the reason that where the floor of the body of water is silty or soft, these cutters have a tendency to cause some of the silty material to float temporarily and then settle back into the trench before the pipeline bottoms in the trench. Where rocks are encountered, the mechanical cutters are quickly dulled, and even when suction dredging is also used, the suction equipment cannot remove large rocks. Water jets are normally wholly ineffective where rocks are encountered. In the case of a bottom composed of clay, the cutters have a tendency to shear off large chunks which cannot be removed effectively with dredging equipment. Trenching with water jets when clay is encountered is very slow and time consuming because of the tenacious nature of the clay.

SUMMARY OF THE INVENTION

The method and apparatus of this invention avoids and substantially alleviates the disadvantages of the prior art techniques and apparatus.

In accordance with the invention, an apparatus is provided which trenches effectively regardless of the nature of the floor of the body of water provided of course that the floor is not solid rock. Trenching operations can be effectively done in floors composed of silt, clay, rocky deposits, or sand, or in floors or bottoms containing a combination of such materials.

While the bottom of a body of water is usually of the same consistency or composition, where long pipelines are to be trenched, changes from, for example, sand to clay or clay with rocks frequently occur.

In accordance with this invention, entrenching can proceed at a relatively rapid rate regardless of the nature of the bottom.

In accordance with this invention, trenching is accomplished by forming a generally V-shaped trench beneath the pipeline by mechanically cutting and conveying the bottom material upwardly and outwardly, with minimum agitation, so that a trench can be effectively formed under the pipeline in clay, rock containing, and sandy or silty bottoms.

In its preferred form, the apparatus uses as combined cutters and conveyors, augers which have at least partially exposed front faces for cutting, and are partly enclosed at their rear portions so that the bottom soil is both cut and conveyed by mechanical means. Upper portions of the augers are provided with surrounding casings to enhance the conveying action above the level of the bottom and these casings extend outwardly to discharge the removed materials to a location outwardly of the formed trench.

The augers are advantageously mounted on a sled or other form of underwater vehicle for pivotal movement from a vertical position in which the augers are spaced apart and straddle the pipeline, to an inwardly inclined position in which the axes of the augers intersect each other at an angle, and the cutting portions of the augers are beneath the pipeline to form a generally V-shaped trench. Further, suitable guides are provided on the vehicle to guide the vehicle along the pipeline during trenching.

In accordance with another feature of the invention, bottom portions of the augers can be exposed so that the augers can form an initial opening for themselves into the material of the bottom. This is especially advantageous where the bottom at the starting point of the trench is composed of clay or contains rocks.

The augers themselves are advantageously cylindrical, but can be conical, of decreasing diameter toward their lower ends. Such construction provides the advantage that choking or jamming of the material in the encased portions of the augers is wholly avoided. A plow or deflector can be provided in the triangular space defined by the underside of the pipeline and the inner sides of the two augers, to direct or force the material in this small triangular sector toward the augers themselves. This triangular sector, however, is normally sufficiently weakened by the action of the augers digging under and along its sides, that this section is removed without difficulty.

In accordance with another feature of the invention, the bottom of each auger is braced and has a bearing to avoid cantilever loading of the augers and to prevent

excessive wear and damage to upper supporting bearings of the augers.

As a result of the upward cutting and conveying action of the augers, even large rocks, if encountered, are effectively removed by being kicked upwardly by the rotating augers. Correspondingly, rocks and stones of a size greater than the thread depth of the auger are effectively removed from the trench by this upward and outward cutting and conveying action of the augers.

In accordance with another feature of the invention, the assemblies including the augers are mounted on the vehicle for vertical adjustment to permit adjusting the apparatus to form trenches of different depths.

Another feature according to the invention is an apparatus in which the upper casings have removable front covers to permit varying the distance from the bottom of an auger assembly to an enclosing casing on the upper portion of the assembly.

A further feature is a deflector plate arrangement removably connected to each auger assembly, and which deflects bottom soil toward the inclined augers for removal.

An additional feature of the invention is an apparatus in which there are two sets of augers, one in tandem behind the other, on the same vehicle, and in which the rear set of augers removes bottom soil which may not have been removed by the front augers.

Other aspects, features, and advantages of the invention will become apparent from the drawings and the detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

While the accompanying drawings show a preferred embodiment, having the features and advantages discussed above, it is to be appreciated that these drawings relate to a typical embodiment and are not to be considered as limiting the scope of the invention.

FIG. **1** is a top plan view of one embodiment of an underwater apparatus according to the invention;

FIG. **2** is a front view in section taken along line **2—2** of FIG. **1**, showing the auger assemblies of the apparatus straddling an underwater pipeline, and positioned to form a trench beneath the pipeline on the floor of a body of water;

FIG. **3** is a side view in section taken along line **3—3** of FIG. **2** and showing an auger assembly with its axis vertical;

FIG. **4** is a partial view in section taken along line **4—4** of FIG. **2**, showing the configuration of a deflector plate;

FIG. **5** is a view corresponding to FIG. **4** and showing a variation of deflector plate;

FIG. **6** is a partial rear view of the auger assemblies in their trenching position and showing the arrangement for keying the lower ends together against relative fore and aft movement;

FIG. **7** shows schematically, a variation of the apparatus of FIG. **1** and in which there are two sets of augers; and

FIG. **8** is a front view in elevation of the apparatus of FIG. **7**.

DETAILED DESCRIPTION

Referring now to the drawings, FIGS. **1–3** in particular, there is shown an apparatus according to the invention for entrenching a pipeline **10** in the floor or bottom **12** of a body of water. This apparatus takes the form of an underwater vehicle **14** which is shown as a sled, but which could take various other forms, such as a crawler or other form of self propelled vehicle.

Vehicle **14** in the form shown, has pontoons **16** and **18** at its opposite sides which are spaced apart a distance greater than the width of the trench to be formed. These pontoons **16** and **18** are advantageously hollow but water tight, and also serve as ballast tanks to permit ballasting the vehicle by pumping water into or out of the tanks. The pontoons **16** and **18** are connected together by the super structure **22** of the vehicle, which can take the form of inverted U-shaped laterally extending structural elements **24–27**, and which provide a generally unobstructed space so that the vehicle can straddle the pipeline, as shown at FIG. **2**. Longitudinal brace elements **28** and **29** extend between the respective elements **24–27** to rigidify the structure. While elements **24–29** are illustrated as pipe-like or tubular, they can of course be of any structural configuration such as I-beams, C-beams, or can be square or rectangular tubes.

Mounted on the vehicle are auger assemblies **32** and **34** forming combined mechanical cutting and conveying assemblies. These assemblies include hydraulic drive motors **36** and **38** at their upper ends, upper conveyor casings **40**, **41**, lower casings **42**, **43**, discharge casings **44** and **46**, and augers **48** and **50**.

Auger **48** has a left hand helical blade or flute whereas auger **50** has a right hand flute. In operation, the augers are rotated in opposite directions, i.e. auger **48** turns counter-clockwise as viewed from above, whereas auger **50** rotates clockwise as viewed from above. Such rotation in opposite directions reduces to a minimum any torques which could cause the vehicle to shift laterally on the pipeline. The cutting edge, i.e. the helical outer edge of each auger blade is preferably smooth and continuous, but can be serrated or toothed.

Lower conveyor casing **42** is cylindrical, and in the region below the surface of bottom **12** of the body of water, has its front open or cut-away so that the front of the lower portion of auger **48** is exposed. The extent of this open portion **54** of the casing is advantageously 180°, or slightly greater, thereby exposing the front of each auger for cutting. Behind this open portion **54** is a generally semicircular portion **56** of the casing.

The bottom end of lower casings **42** and **43** are each open, and the central shaft of each auger extends through a bearing **58** supported by a spider **60** having radially extending circumferentially thin arms **61** secured to lower casing **42**. Of course, the flutes of the auger are discontinuous at the bearing which provides support against lateral bending of an auger, and otherwise resists cantilever forces acting on the lower portions of an auger.

The bottom end of each auger converges and terminates at a sharp cutting tip **62** which facilitates sinking the augers vertically into the bottom material. The blade such as blade **48** of each auger extends from the bottom of the auger assembly to a location adjacent an inlet **64** of discharge casing **44**. Within upper casing **40**, near the upper end of the auger, is a curved deflector **66** which directs material conveyed upwardly by the auger into the inlet **64** of discharge casing **44**. The aguer blade **48** terminates just below deflector **66**. The auger shaft **68** extends through deflector **66** and is connected to the output shaft of motor **36**. An appropriate seal is provided around auger shaft **68** to prevent conveyed material from flowing to the region above the deflector **66**. A bearing (not shown) is provided at the upper end of auger shaft **68**.

As will soon be described in detail, each auger assembly is mounted on vehicle **14** for both pivotal movement and vertical adjustment. As shown at FIG. **2**, the auger assemblies are each moveable to a generally vertical position as shown in phantom lines at the left side of FIG. **2**, and to the working position shown in solid lines at FIG. **2**. It will be observed from FIG. **2** that there is a generally inverted triangular space between the augers and the bottom of pipeline **10** in which the augers do not cut. To prevent material from this triangular region from passing between the augers, a deflector plate assembly **72** is secured to the lower casing of auger assembly **32**, and a similar deflector plate assembly **74** is secured to the lower casing of auger assembly **34**. When the auger assemblies are in their working position as shown at FIG. **2**, the inner edges of the deflector plates meet in a vertical plane which extends longitudinally of the vehicle. When the augers are pivoted to the respective phantom line positions, the respective deflector plates **72** and **74** are located outwardly of the circumference of pipeline **10**.

Mounted on deflector plate **72** behind its front face **78** is a guide roller **80** which projects above the top edge of the deflector plate and is inclined inwardly toward the perimeter of pipeline **10**. Another guide roller **82** is similarly mounted on deflector plate **74**, behind its front face **84**. These guide rollers **80** and **82** function to prevent the top edges of deflector plates **72** and **74** from engaging and thus damaging pipeline **10** or its covering. While rollers **80** and **82** are each shown as single rollers, for purposes of illustration, each of the rollers can of course take the form of a plurality of rollers which perform the desired function of preventing the deflector plates from damaging the pipeline. Deflector plates **72** and **74** are each removeably secured to the respective lower casings **42** and **43**. As shown at FIGS. **1**, **4** and **6**, deflector plate **72** curves rearwardly from top to bottom, and also curves inwardly to direct bottom material in half triangular space between augers toward the auger **48**. Plate **74** is a mirror image of **72** and directs material to auger **50**. The releasable connection takes the form of a series of bolts and nuts **86**. At the connection, deflector plate **72** is bent to provide an offset **88** so that the deflector plate at the connection, merges smoothly with the arcuately curved lower casing **42**. The bolts of the nut-bolt assembly **86** can take the form of studs welded to the rear face of casing **42**, or alternatively, can be bolts with counter-sunk heads extending into counter-sunk openings in casing **42** so that the heads of the bolts are flush with the inside surface of casing **42**.

As shown at FIG. **6**, a transversely extending pin **88** is fixed to the rear face of deflector plate **74**, and a pin receiving block **90** is fixed to the rear face of deflector plate **72**. Formed in block **90** is a vertically elongated opening **92** which extends completely through block **90** to receive pin **88** as the auger assemblies are pivoted together toward their working positions. Opening **92** extends completely through block **90** to permit pin **88** to force bottom material which may be in the opening through the block as it enters and passes through the opening. Pin **88** cooperates with block **90** to form a means for connecting or locking the lower portions of the auger assemblies together against relative movement in a direction fore and aft of vehicle **14**.

As shown at FIG. **1**, deflector plates **72** and **74**, when the augers are in the inwardly sloped working position, meet along their inner edges to form a structure generally similar to an inverted plough. In the embodiment shown at FIG. **4**, the lower casing **42** and deflector plate **72** are so formed as to enclose essentially a 180° sector of auger **48**, which is located behind the auger and leaves a 180° sector of the front face of the auger exposed for cutting.

In the embodiment of FIG. **5** there is shown a deflector plate **72'** connected to a lower casing **42'**. In this embodiment, the lower casing **42'** spans a sector less than 180° about auger **48**, and deflector plate **72'** is so formed that its front face merges tangentially into the inner surface **94** of lower casing **42'**. In the arrangement of FIG. **5**, the curvature of the front face of deflector plate **72'** and inner surface **94** takes the form of a continuous smooth curve.

While the function of the embodiments of deflector plates shown at FIGS. **1–6** is to deflect bottom soil toward the respective augers from the triangular space between the augers, it is to be appreciated that, depending on the type of bottom soil, the deflector plates can either be eliminated or can simply take the form of flat plates, the function of which is to prevent bottom soil from passing to a region behind the augers where it cannot be removed by the augers. Where the bottom material is a very flowable material, the bottom soil will simply flow downwardly and outwardly so that it is removed by the exposed faces of the augers. With such flowable bottom material, it may however be desirable to simply prevent material from passing through the triangular space, in which instance a simple flat plate is all that is needed, the bottom soil in front of the plate simply flowing into the void created by the augers as they remove material from the sides of the trench.

Mounted on the rear of the respective upper casings **40** and **41** are guide roller assemblies **96** and **98**, the purpose of which is to prevent the auger assemblies from engaging and damaging pipeline **10**. Roller assemblies **96** and **98** have axes of rotation which are respectively parallel to the axis of rotation of the respective augers. These roller assemblies are however offset rearwardly behind the planes of the rollers **80** and **82**, for a reason which will soon become evident.

The upper casings **40** and **41** each have removable front portions which take the form of generally semicircular removable casing sections **102** and **104** respectively. This type of construction in essence provides a lower section of the upper casing which is vertically split in a lateral plane. Such construction permits removing the front casing sections **102** and **104** and substituting sections of different length so that the respective bottom edges **106** and **108** of the upper casings will be just above the level of the bottom material **112**, regardless of the vertical adjustment of the auger assemblies.

As shown at FIGS. **1–4**, for the auger assembly **32**, mounting blocks **112** and **114** are fixed to the rear outside surface of the auger casing. Formed in each of the mounting blocks **112** and **114** is a T-slot **116**, and the T-slots of the blocks **112** and **114** are each parallel to the axis of auger **48** and are aligned with each other.

Each auger assembly is mounted on vehicle **14** for both vertical adjustment and pivotal movement about an axis parallel to the longitudinal axis of the vehicle. The mounting arrangement includes a mounting structure **118** which is essentially identical for each auger assembly. Mounting structure **118** includes an upright element **120** in the form of an I-beam, a longitudinal element **122** welded to the I-beam at its forward end, and a diagonally extending brace element **124** welded

between the lower end of the I-beam and the rearward end of the element **122**. Fixed to element **122** are clevis assemblies **124** and **126** which receive therein bearing blocks **128** and **130** respectively, and which are fixed to and extend downwardly from the respective cross elements **26** and **27** of vehicle **14**. Pivot pins **132** are used to then pivotally mount structure **118** on the vehicle. The auger assemblies are in turn mounted on the vehicle by sliding the front flange **134** of I-beam **120** through the T-slots **116** of the respective mounting blocks **112**. When bolts **136** of the mounting blocks are tightened, an auger assembly is fixed to the structure **118**. Loosening bolts **136** provides for removing the auger assemblies by sliding them in a direction parallel to the length of I-beam **120**. Further, it will be appreciated that each auger assembly can be adjusted vertically on I-beam **120**, simply by loosening bolts **136** and lifting or lowering the assembly. The T-slot and I-beam arrangement further permit simply sliding an auger assembly off the I-beam flange to remove the assembly from the vehicle.

A hydraulic cylinder **140** has its cylinder end connected to cross element **26** at a pivot connection **142**, and its rod end connected to I-beam **120** at a pivot connection **144**. Pivot connection **144** has its axis below the axis of mounting pins **136** so that introducing hydraulic fluid under pressure into the cylinder or head end of cylinder **140** pivots mounting structure **118** and the auger assembly **32** mounted thereon to the working position shown at FIGS. **1** and **2**. Introducing hydraulic fluid under pressure to the rod end of cylinder **140** pivots the auger to the phantom line position shown at line **2**. Hydraulic cylinder **146** is provided for moving auger assembly **34** from its generally upright position to the inwardly slanted position shown at FIG. **2**.

Projecting downwardly below cross element **26** are roller assemblies **152** and **154** which slope downwardly toward the pipeline, and the function of which is to prevent engagement of cross member **26** with the surface of the pipeline which could damage the pipeline. Rollers **152** and **154** slope toward each other so that they also guide the vehicle along the pipeline in the event that the rollers engage the pipeline. Rollers similar to rollers **152** and **154** are provided on each of the cross elements **24**, **25**, and **27** to prevent damage to the pipeline by any of the cross elements of the vehicle **14**, and to guide the vehicle.

At the front of the vehicle on the respective pontoons **16** and **18** are clevices **158** and **160**. These clevices are provided to receive a bridle (not shown) for towing the vehicle along the ocean floor with the bridle from a barge located substantially in front of the vehicle, on the surface, and directly above the pipeline. Where the vehicle is of the self-propelled type, connections will not be required to pull the vehicle, but it will still be necessary to provide hydraulic lines from a surface vessel to drive hydraulic motors **36** and **38**, and conrol lines to operate cylinders **140** and **146**.

OPERATION

For purposes of this explanation it is assumed that pipeline **10** is already on the floor of a body of water and is to be entrenched. The entrenching apparatus, i.e. vehicle **14** is transported to a location immediately above where entrenching will begin. The depth of the trench to be formed will be predetermined on the basis of the diameter of the pipeline and other considerations such as the depth of the water where the pipeline is entrenched. For a 36 inch diameter pipe there is usually a requirement for at least a three foot over-burden, and correspondingly, the trench formed must be six feet deep. Where more over-burden is required, deeper trenches must be formed, for example ten feet deep. In accordance with the invention, the entrenching apparatus disclosed herein can be adjusted and adapted to form trenches of different depths and can be used to entrench pipelines and other elongate underwater structures of different sizes.

Assuming that the entrenching apparatus is carried to the site of use on a barge, there will also be on the barge several sets of deflector plates **72**, **74**, as well as several sets of casing extensions **102**, **104**. There can for example be three sets of deflector plates **72**, **74**, one set for use in forming a six foot trench, one set for use in forming an eight foot trench, and one set for use in forming a ten foot trench. These deflector plates will have approximate vertical heights of six feet, eight feet, and ten feet, respectively. The sets of casing covers **102**, **104** will then differ in length by a distance of two feet so that the bottom edge of the casing cover will be approximately at the level of the bottom soil when the auger assemblies are in their working position as shown at FIG. **2**.

The embodiment of FIG. **2** illustrates the arrangement of the apparatus for forming an eight foot deep trench. Deflector plates **72** and **74** have a height of approximately eight feet and casing covers **102** and **104** are about two and one half feet in length as measured axially of an auger. Where the trench formed is ten feet deep, ten foot high vertical deflector plates would be used and the casing covers would be perhaps only several inches in height and would simply function as replacable wear plates on the upper casing. On the other hand, where a six foot trench is formed, deflector plates **72** and **74** would be six feet high and casing covers **102**, **104** would each be about four and one half feet long.

After a selected set of deflector plates and casing covers are bolted onto the auger assemblies, bolts **136** are loosened, and each auger assembly is adjusted vertically on its supporting I-beam **120** to an appropriate elevation relative to the vehicle so that the bottom edges **106** and **108** of the casing covers will be at approximately the level of the surface of the bottom soil when the augers are in their working positions of FIG. **2**. With the entrenching apparatus so adjusted and assembled, hydraulic lines to drive motors **36** and **38** are connected between the barge and the vehicle, and control lines are also connected to control the operation of the cylinders **140** and **146** for tilting auger assemblies **32** and **34**.

While on the barge, the vehicle will be carried in a suitable cradle, and cylinders **140** and **146** will be pressurized at their rod ends to maintain each auger assembly in a generally vertical position as shown in phantom lines at FIG. **2** for auger assembly **32**.

Next, the vehicle will be lowered to the bottom of the body of water to a position in which the pipeline is aligned between the still vertical augers. The vehicle will then be further lowered until the pontoons **16** and **18** are supported on the bottom surface **12**. During such final lowering, depending on the nature of the bottom material, augers **48** and **50** can be rotated to plunge the auger assemblies into the bottom material. Next, the head ends of cylinders **140** and **146** are pressurized to urge the augers to the inwardly inclined working position as shown at FIG. **2**. Depending on the nature of the bottom material, it may be necessary to pull the vehicle forward while rotating the augers and maintaining pres-

sure in the head ends of cylinders **140** and **146** to enable the augers to ultimately swing to the FIG. **2** position. Where a relatively hard bottom material is encountered, it may be necessary to form a short length of trench beneath the pipeline, using jetting equipment which is normally carried by the barge.

With the entrenching apparatus in its working position, vehicle **14** is pulled along pipeline **10** while augers **48** and **50** are rotated. The speed of rotation of the augers will depend on the nature and consistency of the bottom material. Where the bottom material is relatively soft, such as "sugar sand," a relatively high rotational speed is required to cut and convey the sand upwardly and direct it outwardly through discharge chutes **44** and **46**. It will be appreciated that during cutting and conveying, water is also conveyed so that the material within the upper casings, such as casing **40**, is more or less in the form of a slurry.

Where the bottom material is of a harder consistency such as clay, a lower speed of rotation is desirable to cut the clay, the relatively large pieces formed by such cutting being easily conveyed by the auger to the discharge chute which it will be noted, slopes downwardly from the augers in the working position.

It will be appreciated that the mounting assembly **118** takes the form of a triangular structure, and that the I-beam **120** of this structure tends to reinforce the auger casings against fore and aft bending when the augers are in operation. Further, the brace **124** of structure **118** has the effect of reinforcing the I-beam **120** against fore and aft bending. In addition, when the augers are pivoted to their inclined working positions, pin **88** of deflector **74** enters slot **92** of block **90** to key the auger assemblies together against relative fore and aft movement at their lower ends. In this way, the auger assemblies reinforce each other against the effects of bending forces which can occur if a hard object is encountered by the augers. One or more additional pin and slot assemblies can be provided along the vertical height of the rear faces of the deflector plates to further key the deflector plates together and thus avoid the effects of forces tending to cause rearward bending.

FIGS. **7** and **8** show a second embodiment of entrenching apparatus according to the invention. Entrenching apparatus **200** is in many ways similar to the entrenching apparatus of the embodiment of FIGS. **1–6** save that it includes two sets of augers mounted in tandem on a vehicle **202**. Vehicle **202** includes pontoons **16'** and **18'**, a plurality of spaced-apart cross members **204–208**, and longitudinal structural elements **28'** and **29'**. The front auger assemblies **210, 212** are essentially identical to auger assemblies **32** and **34** and include replacable front casing covers **102** and **104**, but as will soon be explained, deflector plates **72, 74** are not used in this embodiment. Further, auger assemblies, **210** and **212** each have a series of guide rollers **214** and **216** which extend along a substantial length of the auger assemblies as shown at FIG. **8**. Individual ones of the rollers comprising these roller assemblies are detachably connected to the respective auger assemblies. Rear auger assemblies **218** and **220** are identical respectively with auger assemblies **210** and **212**.

Each auger assembly is mounted on the vehicle by means of a mounting structure (not shown in FIGS. **7** and **8** but which is identical to the mounting structure **118** previously described and which is shown at FIG. **3**.)

In the embodiment of FIGS. **7** and **8**, a pin and slot assembly **222** can be provided adjacent the bottom end of the respective auger assemblies to key the auger assemblies against relative fore and aft movement when they are in the working positions shown at FIGS. **7** and **8**. Assembly **222** is essentially the same as that shown at FIG. **6** save that the pin and block are mounted directly on the auger casing rather than the deflector plates which are not used.

OPERATION—EMBODIMENT FIGS. 7 AND 8

Use and operation of entrenching apparatus **200** of the embodiment of FIGS. **7** and **8** is similar to that previously described for the embodiment of FIGS. **1–6**.

Each auger assembly is adjusted on its I-beam **120** to a position to form the trench of the desired depth. Casing covers **102, 104** of a proper length for the depth of the trench to be formed are then selected and bolted to both the front and rear auger assemblies. The auger assembly tilting cylinders are then actuated to place each auger assembly in a vertical position.

Next, the vehicle **202** is lowered so that both the front and rear augers straddle the pipeline. Next, the augers are tilted inwardly to the working positions shown at FIGS. **7** and **8**, the drive motors are actuated, and the vehicle is moved forward in the direction of arrow **230** of FIG. **7**. Augers **210** and **212** cut along the sides of a generally trapezoidal section immediately beneath pipeline **10** and convey this material to locations at the sides of the trench thus formed. The remaining material in the triangular sector **240** between the augers, and which does not flow and is not drawn toward the augers by evacuating the material from the sides of this sector, falls to the bottom of the trapezoidal sector. This bottom material which is missed by the front augers **210** and **212** is cut and conveyed by the rear augers **218, 220** to provide a generally trapezoidal-shaped trench beneath the pipeline.

Depending on the nature and consistency of the bottom material, deflector plates like **72** and **74**, previously described, can be provided on rear auger assemblies **218** and **220**.

Also, depending on bottom conditions encountered, the first augers **210, 212**, can be set at a greater (or lesser) depth than the rear augers **218, 220**. Further, deflector plates can be used on both the front and rear augers, so that the front auger forms a shallow trench, and the rear augers a deeper trench.

In view of the foregoing description it is believed evident that in accordance with this invention, there is provided a unique method and apparatus for entrenching elongated submerged structures and which avoids the disadvantages and shortcomings of the prior art jetting or mechanical entrenching devices.

While two preferred embodiments of an apparatus according to the invention have been shown and described, it is believed evident that changes can be made without departing from the scope of this invention.

What is claimed is:

1. Apparatus for entrenching an elongate submarine structure such as a pipe or cable comprising

a vehicle having a front and a rear and adapted to be moved along the floor of a body of water;

a first auger assembly mounted at a location offset toward one side of the vehicle;

a second auger assembly mounted at a location offset toward the other side of the vehicle;

means mounting said assemblies on said vehicle for movement to a first position in which the augers are spaced apart to receive therebetween the pipeline to be entrenched, and to a second position in which the augers are inclined inwardly and lower end portions of the auger assemblies are adjacent to each other beneath the elongate structure;

motor means on said vehicle for moving said augers to said first and second positions;

each auger assembly comprising

an auger having an upper portion and a lower portion;

motor means for rotating the auger;

a casing partially surrounding said lower portion to leave a front face of the auger exposed for cutting, said casing cooperating with said auger to convey bottom material toward the upper portion of the auger; and

casing means substantially enclosing said upper portion and cooperating with said upper portion for conveying the material away from the trench thus formed by the augers.

2. Apparatus according to claim **1** further comprising means for connecting the lower portions of the auger assemblies together beneath the elongated structure to prevent relative fore and aft movement of the lower portions of the assemblies relative to each other.

3. Apparatus according to claim **1** further comprising brace means on said vehicle for bracing the lower end of each auger assembly.

4. Apparatus according to claim **1** further comprising roller means on said vehicle and surrounding said elongate structure when said auger assemblies are in said second position, for guiding the vehicle with respect to the elongate structure.

5. Apparatus according to claim **1** wherein each auger has a bottom end comprising cutting means for cutting downwardly into the bottom material.

6. Apparatus according to claim **1** wherein each auger assembly further comprises bearing means adjacent a lower end of the auger for supporting said lower end for rotation.

7. Apparatus according to claim **6** wherein

each auger comprises a journal in the lower portion therof at a location spaced from the bottom end of the auger;

the auger has a blade which is discontinuous at said journal; and

said bearing means supports said journal for rotation therein.

8. Apparatus according to claim **1** wherein

said augers of said assemblies, in said second position, cut and convey bottom material from the sides of a generally trapezoidal shaped section beneath the elongated structure; and

said apparatus comprises further means supported by the vehicle for further removing bottom material from beneath the elongated structure.

9. Apparatus according to claim **8** wherein said further means comprises third and fourth auger assemblies like said first and second assemblies and spaced behind said first and second assemblies.

10. Apparatus according to claim **1** further comprising

deflector means on said apparatus beneath said pipeline for deflecting bottom material laterally toward said augers.

11. Apparatus according to claim **1** wherein

each auger assembly further comprises discharge chute means for directing material from said upper portion of an auger to a location laterally spaced from the trench formed by the auger.

12. Apparatus according to claim **1** further comprising means mounting said auger assemblies on said vehicle for vertical adjustment to vary the depth of the trench formed by the augers.

13. Apparatus according to claim **12** comprising deflector means on said vehicle for deflecting bottom material toward said augers, and means to permit changing the height of the deflector means with respect to the augers.

14. Apparatus according to claim **12** comprising means to permit changing the length of the exposed portion of the front face of each auger.

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